TUNING OF OPTICAL DEVICES

Field of the Invention

The present invention relates to the thermal processing of waveguides so as to alter their properties.

Background of the Invention

The construction of planar optical waveguide devices is well known. These normally are constructed by depositing layers on top of a silicon substrate with portions of the deposited (and etched) layers being made photosensitive and subsequently being subjected to light of a wavelength selected to manipulate their optical properties. In this manner, often extremely complex optical waveguide devices can be built up on a silicone substrate.

It is desirable to provide for a system of post processing of the optical waveguide so as to tune the properties of any complex device of which the waveguide forms part.

Summary of the Invention

In accordance with a first aspect of the present invention, there is provided a method of tuning an optical device incorporating a waveguide, the method comprising the step of applying a localised heating to the device in order to change the optical properties of the waveguide.

The localised heating can be applied by means of a laser device such as a UV or Infra Red laser device.

The device may comprise the waveguide formed on a substrate.

The method can e.g. be utilised in the tuning of one arm of an interferometric device.

The localised heating can be used to cause thermal relaxation, thermal diffusion or induce structural changes in the device.

In one embodiment, the method can be used to write a grating structure into the waveguide.

Brief Description of the Drawings

Notwithstanding any other forms which may fall within

the scope of the present invention, preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 illustrates schematically the process of thermal process of waveguides;

Fig. 2 illustrates an example application in a MZI type device; and

Fig. 3 illustrates an alternative form of processing of a waveguide type device.

Fig. 4 illustrates the relation between β_{stress} and β_{form} in a method embodying the present invention.

Description of Preferred and Other Embodiments

In the preferred embodiment, local thermal processing of a wafer is carried out utilizing an infra-red or UV laser device. Suitable thermally sensitive waveguides, including a negative index grating within a germanosilicate planar waveguide, can be produced by utilizing a hollow cathode plasma enhanced chemical vapour deposition (HCPECVD)process such as that outlined in M V Bazylenko, M Gross, A Simonian, P L Chu, Journal of Vacuum Science and Technology, A14, (2) pp336-345, 1996 and J Canning, D Moss, M Aslund, M Bazylenko, Election Letters, 34(4) pp366-367 (1998).

Turning now to Figure 1, the localised heating is preferably in the region of the waveguide 1 so as to alter its optical properties. Preferably, the thermal processing utilised is designed to have minimal other effects on the waveguide 1.

Hence, if a UV laser is to be utilised then may be utilised on the silicon substrate 2 which is opaque to UV rays, as illustrated by arrow 10, whilst for a IR laser may be utilised from above the waveguide 1 as illustrated by arrow 12.

The localised heating can be utilised to cause localised changes in the device 14. The changes can include thermal relaxation of internal stresses, thermal diffusion of material or thermal damage of material layers.

For example, Fig. 2 illustrates an add-drop multiplexer 10 constructed utilizing a Mach-Zehnder principle which can be initially constructed on a wafer and subsequently tuned by means of thermal rather than UV tuning of the arms at the points eg. 11, 12.

Where it is desired to utilise local radiation which may cause undesirable effects in the waveguide 100, as illustrated in Fig. 3, an opaque layer eg. 15 can be formed over the waveguide 100 so as to minimise photosensitive alternations in the area of waveguide 100.

The utilisation of local heating can have a number of uses. Firstly, as noted previously, there is its utilisation to change waveguide properties. Such utilisation would be ideal for example in Mach-Zehnder type devices. Other devices could include multimode devices wherein each arm can be thermally processed so as to adjust properties.

An alternative use for localised thermal heating is the localised heating of the substrate/wafer to control or release stresses through annealing or damaging of the wafer. E.g. it is known to construct optical waveguide devices having internal waveguide structures utilizing plasma enhanced chemical vapour deposition processes on a silicon substrate. Unfortunately, often non-symmetrical birefringence effects will result form the formation process. The first birefringent effect denoted β_{form} will be due to the circumference characteristics of the waveguide. The second effect denoted β_{stress} will be due to several stresses associated with the thermal coefficient mismatch of the substrate and deposited layer.

In an embodiment of the present invention, localised thermal heating of the above described structure could thus provide a method to alter the overall birefringence in the waveguide by either releasing existing stresses or introducing further stresses. E.g, as illustrated in Figure 4, where the "sign" of β_{stress} 200 is opposed to that of

β_{form} 202, the resultant birefringence 204 can be nullified by introducing further stresses in the direction of β_{stress} 200.

Alternatively, the localised thermal heating can be utilised as a form of annealing so as to slowly anneal the whole of a wafer whilst simultaneously measuring the waveguide properties. In this manner, the whole of the substrate can be thermally annealed on a mount with localised heating providing for a more precise annealing than that available through the utilisation of general convection heating. In this manner, the thermal annealing can be closely monitored and altered at any particular point.

The principle of localised thermal heating can be extended to the actual direct writing of thermally created device structures utilizing a small spot size for thermally induced rather than optically induced alternation of the waveguide. Again, this can be utilised for post processing of a waveguide so as to perform tuning or, alternatively, for the construction of more complex waveguide devices.

An example application is a process of polarisation control by heating of a substrate. An ideal laser source can be diode bar array at 810nm which is absorbed by the substrate and the waveguide. A CO/CO_2 laser can be used to heat the surface and affect the internal waveguides. Further, the devices can be tuned either at the waveguide or at the substrate. Preferably, an IR source is used so as to thermally heat and not damage the substrate.

It would be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

We Claim:

1. A method of tuning an optical device incorporating a waveguide, the method comprising the step of applying a localised heating to the device in order to change the optical properties of the waveguide.

2. A method as claimed in claim 1 wherein said localised heating is applied by means of a laser device.

3. A method as claimed in claim 2 wherein said laser device comprises a UV or Infra Red laser device.

4. A method as claimed in any previous claim wherein said method is utilised in the tuning of one arm of an interferometric system.

5. A method as claimed in any previous claim wherein said method is utilised in the thermal annealing of a substrate on which said waveguide is formed.

6. A method as claimed in any previous claim wherein said localised heating causes thermal relaxation, thermal diffusion or induces damage in said substrate.

7. A method as claimed in any previous claim further comprising the step of utilising said heating to write a structure into said waveguide.

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

RECD 20 FEB 2001
WIPO PCT

Applicant's or agent's file reference FP11656	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International Application No. **PCT/AU99/00998**	International Filing Date *(day/month/year)* 12 November 1999	Priority Date *(day/month/year)* 12 November 1998

International Patent Classification (IPC) or national classification and IPC

Int. Cl.[7] G02B 6/12, H01L 21/324 , 21/477

Applicant

THE UNIVERSITY OF SYDNEY et al

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

[X] This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 7 sheet(s).

3. This report contains indications relating to the following items:

I	[X]	Basis of the report
II	[ ]	Priority
III	[X]	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	[ ]	Lack of unity of invention
V	[X]	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	[ ]	Certain documents cited
VII	[ ]	Certain defects in the international application
VIII	[ ]	Certain observations on the international application

Date of submission of the demand	Date of completion of the report
31 May 2000	19 January 2001
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **DEAN ALLE** Telephone No. (02) 6283 2286

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/AU99/00998

I. Basis of the report

1. With regard to the **elements** of the international application:*

☐ the international application as originally filed.

☒ the description, pages , as originally filed,
pages , filed with the demand,
pages **1, 1A, 2, 3, 4** received on **6 December 2000** with the letter of **6 December 2000**

☒ the claims, pages , as originally filed,
pages , as amended (together with any statement) under Article 19,
pages , filed with the demand,
pages **5, 6** received on **6 December 2000** with the letter of **6 December 2000**

☒ the drawings, pages **1/2 - 2/2** as originally filed,
pages , filed with the demand,
pages , received on with the letter of

☐ the sequence listing part of the description:
pages , as originally filed
pages , filed with the demand
pages , received on with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

☐ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, was on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages

☐ the claims, Nos.

☐ the drawings, sheets/fig.

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report*

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be nonobvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application,

☒ claims Nos: **11**

because:

☐ the said international application, or the said claims Nos. **11** relate to the following subject matter which does not require an international preliminary examination *(specify)*:

☒ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. **11** are so unclear that no meaningful opinion could be formed *(specify)*:

Claim 11 does not comply with rule 6.2(a) because it makes undue reference to the description.

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☐ no international search report has been established for said claim Nos.

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

☐ the written form has not been furnished or does not comply with the standard.

☐ the computer readable form has not been furnished or does not comply with the standard.

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 20 June 2000 (20.06.00)	
International application No. PCT/AU99/00998	**Applicant's or agent's file reference** IHA:FP11656
International filing date (day/month/year) 12 November 1999 (12.11.99)	**Priority date** (day/month/year) 12 November 1998 (12.11.98)
Applicant CANNING, John et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

31 May 2000 (31.05.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Claudio Borton
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

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